PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Patrick DUVAUT et al — Attorney Docket Q62126

Filed : December 21, 2000 — Our ref 120313 AN

For : METHOD AND APPARATUS FOR DETERMINING PROPERTIES OF A TRANSMISSION CHANNEL.

DECLARATION

I, Caroline Heyndrickx, hereby declare that :

1. I am employed by Alcatel, the owner of the above application.
2. The inventors were employed by Alcatel at the time of the invention.
3. On December 1, 2000 I sent the Declaration and Power of Attorney as well as the Assignment papers to Luc Descamps and Thierry Doligez, for execution by the inventors. The papers were returned to me with the signatures of those two inventors and I was advised that Mr. Patrick Duvaut was no longer employed by Alcatel and I was also advised that nobody knew where he was living or working. One supposed he was living in the U.S.
4. On December 1, 2000 I also sent the same documents to Mr Patrick Duvaut to his last known home address in France by UPS Courier. UPS package was returned to me on December 4, informing there was no person living at this address by the name of P. Duvaut.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United State Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date : January 16, 2001

By : ______________________
Caroline Heyndrickx

Waybill Here

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CONTACTPERSON / CONTACT DUVAUT

TELEFOONNR. / TELEPHONE NO.

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POSTCODE / POSTAL CODE 9530 Routot

LAND / COUNTRY

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REFERENTIENUMMER 1 / REFERENCE N° 1

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ALCATEL

WITH THE COMPLIMENTS OF

Carol,

Please find attached the filled document. As you know, Patrick Ducant is no longer in France and we don't know his new address so he didn't sign the document.

Best regards,

Luc Dekamp.

Alcatel ETCA s.a., rue Chapelle Beaussart 101, B-6032 Mont-sur-Marchienne, Belgium
Tel. (32/71) 44 22 11 - Telefax (32/71) 44 22 00

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1 OF 1

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(421) 056 2018

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SHIPPER'S SIGNATURE	DATE OF SHIPMENT

December 01, 2000

To : P. DUVAUT

From : C. HEYNDRICKX DT1
ALCATEL BELL
Fr. Wellesplein 1
2018 ANTWERPEN

Subject : Documents for USA

Enclosed some forms which have to be underwritten by the inventors.

Please check the forms and write on each one your full name, no signature permitted !

Then send them back **as soon as possible**.

Regards,

Carol Heyndrickx
DT1

UPS 1/12

W625 321 8328

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SOLE/JOINT

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name: that I verily believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter claimed and for which a patent is sought in the application entitled:

METHOD AND APPARATUS FOR DETERMINING PROPERTIES OF A TRANSMISSION CHANNEL

which application is:

X the attached application
(for original application)

APR 03 2001

☐ Application No. ______
filed , and amended on ______
(for declaration not accompanying application)

that I have reviewed and understand the contents of the specification of the above-identified application, including the claims, as amended by any amendment referred to above; that I acknowledge my duty to disclose information of which I am aware which is material to the patentability of this application under 37 C.F.R. 1.56, that I hereby claim priority benefits under Title 35, United States Code §119, §172 or §365 of any provisional application or foreign application(s) for patent or inventor's certificate listed below and have also identified on said list any foreign application for patent or inventor's certificate on this invention having a filing date before that of any foreign application on which priority is claimed:

Application Number	Country	Filing Date	Priority Claimed Yes	Priority Claimed No
99403245.6	EUROPE	December 21, 1999	x	☐

I hereby claim the benefit of Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in a listed prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge my duty to disclose any information material to the patentability of this application under 37 C.F.R. 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application No.	Filing Date	Status

I hereby appoint John H. Mion, Reg. No. 18,879; Thomas J. Macpeak, Reg. No. 19,292; Robert J. Seas, Jr., Reg. No. 21,092; Darryl Mexic, Reg. No. 23,063; Robert V. Sloan, Reg. No. 22,775; Peter D. Olexy, Reg. No. 24,513; J. Frank Osha, Reg. No. 24,625; Waddell A. Biggart, Reg. No. 24,861; Louis Gubinsky, Reg. No. 24,835; Neil B. Siegel, Reg. No. 25,200; David J. Cushing, Reg. No. 28,703; John R. Inge, Reg. No. 26,916; Joseph J. Ruch, Jr., Reg. No. 26,577; Sheldon I. Landsman, Reg. No. 25,430; Richard C. Turner, Reg. No. 29,710; Howard L. Bernstein, Reg. No. 25,665; Alan J. Kasper, Reg. No. 25,426; Kenneth J. Burchfiel, Reg. No. 31,333; Gordon Kit, Reg. No. 30,764; Susan J. Mack, Reg. No. 30,951; Frank L. Bernstein, Reg. No. 31,484; Mark Boland, Reg. No. 32,197; William H. Mandir, Reg. No. 32,156; Brian W. Hannon, Reg. No. 32,778; Abraham J. Rosner, Reg. No. 33,276; Bruce E. K ner, Reg. No. 33,725; Paul F. Neils, Reg. No. 33,102; Brett S. Sylvester, Reg. No. 32,765; Robert M. Masters, Reg. No. 35,603, G rge F. Lehnigk, Reg. No. 36,359, John T. Callahan, Reg. No. 32,607 and Steven M. Gruskin, Reg. No. 36,818, my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and request that all correspondence about the application be addressed to **SUGHRUE, MION, ZINN, MACPEAK & SEAS, PLLC**, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037-3213.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date January 16, 2001 First Inventor Luc François DESCAMPS
First Name Middle Initial Last Name

Residence GERPINNES BELGIUM Signature Luc François DESCAMPS
City State/Country

Post Office Address: Allée des Templiers (LOV) 23 – B-6280 GERPINNES BELGIUM

Citizenship BELGIUM

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or Non-U.S. Clients

Assignment

Whereas, I/We, (names of inventors and addresses - city and country), respectively, hereinafter called assignor(s), have invented certain improvements in

METHOD AND APPARATUS FOR DETERMINING PROPERTIES OF A TRANSMISSION CHANNEL

and executed an application for Letters Patent of the United States of America therefor on

and

Whereas,

ALCATEL, 54, rue La Boétie, F-75008 PARIS, FRANCE

desires to acquire the entire right, title, and interest in the application and invention, and to any United States patents to be obtained therefor;

Now therefore, for valuable consideration, receipt whereof is hereby acknowledged,

I/We, the above named assignor(s), hereby sell, assign and transfer to the above named assignee, its successors and assigns, the entire right, title and interest in the application and the invention disclosed therein for the United States of America, including the right to claim priority under 35 U.S.C. §119, and I/we request the Commissioner of Patents to issue any Letters Patent granted upon the invention set forth in the application to the assignee, its successors and assigns; and I/we will execute without further consideration all papers deemed necessary by the assignee in connection with the United States application when called upon to do so by the assignee.

I/We hereby authorize and request our attorneys SUGHRUE, MION, ZINN, MACPEAK & SEAS of 2100 Pennsylvania Avenue, NW, Washington, DC 20037-3212 to insert here in parentheses (Application number ________________, filed ________________) the filing date and application number of said application when known.

Date: January 16, 2001 Luc François DESCAMPS
s/ (Luc François DESCAMPS)

Date: January 16, 2001 Thierry Christian Marie DOLIGEZ
s/ (Thierry Christian Marie DOLIGEZ)

Date: ________________
s/ (Patrick DUVAUT)

(Legalization not required for recording but is prima facie evidence of execution under 35 U.S.C. §261)

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Date January 16, 2001 Second Inventor Thierry Christian Marie DOLIGEZ

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First Name Middle Initial Last Name

Residence Signature

City State/Country

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Citizenship

Date Fifth Inventor

First Name Middle Initial Last Name

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Date Sixth Inventor

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Post Office Address:

Citizenship

METHOD AND APPARATUS FOR DETERMINING PROPERTIES OF A TRANSMISSION CHANNEL

The invention relates to a method and apparatus for determining properties of a transmission line or channel, for instance a channel for transmitting electric or acoustic signals. It concerns also a time domain reflectometry method and an equipment for implementing this method.

In the field of telecommunications, the density of transmitted information increases regularly. This increase is not always compatible with the existing equipment, more particularly with the existing transmission lines. In order to cope with this problem, several technologies are known, for instance ADSL which means "Asymmetric Digital Subscriber Line" (or other DSL services such as HDSL and VDSL). This technology provides the possibility to transmit, with ordinary telephone lines, high data rate from the network (a central office) to the subscriber and lower data rates from the subscriber to the network.

ADSL is adapted for distances, between a central station or office and the subscriber, which are comprised between 1.5 and 6 km. HDSL is adapted for distances greater than 6 km, and VDSL is adapted for distances comprised between 0.3 and 1.5 km.

In order to be able to comply with ADSL services, the telephone line must satisfy standards of quality which are not necessarily fulfilled by all telephone lines.

Before implementing ADSL services, it is therefore necessary to evaluate a priori the line quality at the lowest cost as possible and with the highest accuracy as possible. The present invention relates to a method and an apparatus which determine, from a central office, the transmission characteristics of a transmission line with a high signal to noise ratio and a high accuracy.

The invention thus contributes to the line qualification.

Up to now an a priori line qualification requires to make tests at both ends of the line. This means that one operator must be present at the central office and another operator at the subscriber's location. Although accurate, this a priori line testing is expensive.

The method according to the invention is characterized in that, for testing a line, use is made of time domain reflectometry wherein, at one end of the line, a plurality of pulses covering different bandwidths are transmitted in the line and the corresponding echoes are processed, more particularly filtered and reconstructed, at the same end, the echoes providing information about the whole length of the line.

Up to now, time domain reflectometry has been used only for detecting the first defect on a line. Time domain reflectometry is known to use only one pulse of narrow or wide frequency band at one time and the transmitted pulse provides only one echo. With the wide band "multifocal" (multi echoes) time domain reflectometry according to the invention, several echoes are provided which give information about the entire length of the line. In fact, with the invention, which makes use of pulses at different bandwidths, it is possible to optimize both the time accuracy and, with an appropriate filtering, the signal to noise ratio along the whole line, at any distance from the central office.

The plurality of pulses, called here "multifocality", allows to partially compensate for limited dynamics of the A/D (analog to digital) converters. In fact, with only one wide band pulse, it would be necessary to use a pulse of very high amplitude in comparison to the A/D converter ability.

In a preferred embodiment, the pulses are analytical complex pulses and contribute to a high signal to noise ratio.

Preferably the bandwidths of the transmitted pulses are overlapping and are such that the reconstructed echoes present a flat spectrum, i.e. a perfect line. In other words, without defects and without attenuation, the response has practically a constant amplitude over the whole useful frequency spectrum. In this way, the method provides directly the reflectometric impulse response of a line, for instance of a copper pair, generally a twisted pair.

As the pulses cover different bandwidths, in order to obtain this flat spectrum, it is necessary that, after reflection and processing, the modulus of the sum of the complex responses of the overlapping regions equals the modulus (for instance one) in the non-overlapping region.

In a preferred embodiment, the spectrum amplitude on one side of a bandwidth is decreasing according to a sine function and the overlapping part of the neighboring bandwidth is increasing according to a cosine function and the detected signal is the sum of squares of all components.

With this embodiment, after reflection, the first end of the first bandwidth will vary as $\sin^2$ and the overlapping adjoining beginning of the following bandwidth will vary as a cosin^2. Therefore, in the overlapping region: $\sin^2 + \cos^2 = 1$.

With this embodiment, it is also possible to provide a given gain (or attenuation) to each bandwidth in order that, for each of these bandwidths, the pulse be compatible with the power limitations imposed by standards. For instance, ADSL requests that the power be limited to –40 dbm/hertz (10^{-4} mwatt/hertz) and VDSL

requests a limitation to –60 dbm/hertz (10^{-6} mwatt/hertz) for frequencies higher than 1 MHz.

Therefore, in order to obtain a flat spectrum, for each bandwidth, the transmitted pulse has a given amplification (or attenuation) and the received echo is provided with a complementary attenuation (or amplification).

The echoes provide in the time domain, and/or in the frequency domain, an information about the properties, generally the defects, of the line. Moreover, the positions in time of the echoes represent the locations of the defects.

In an embodiment, the frequency bandwidth and the amplitude of the low frequency pulses are selected according to the line attenuation and its compliancy in terms of egress. An egress compliant line is a line which does not disturb neighbouring services. In other word means are provided for selecting the frequency bandwidth and the amplitude of the low frequency pulses.

The time domain reflectometry method according to the invention is not limited to the estimation of the attenuation of telephone lines. More generally, this method may be used for estimating transmission channels which are dispersive, and subject to attenuation and noise.

These channels are not necessarily channels for transmitting electric signals; the signals may be of a different nature, for instance acoustic signals. The method provides the reflectometric impulse response with a good accuracy and a good signal-to-noise ratio at any distance.

In brief, the invention concerns a time domain reflectometry method for estimating properties of a transmission channel, for instance a channel for transmitting electric or acoustic signals, which is characterized in that it comprises the steps of generating, at one end of the channel, a plurality of pulses covering different frequency bands, and of processing the echoes provided by these pulses at the same end of the channel . The invention therefore determines a priori the reflectometric impulse response of this transmission line since it is to be noted that a spectrum over a wide bandwidth is equivalent to a Dirac function.

The invention relates also to a method for testing the properties, such as the attenuation, of telephone lines comprising copper pairs, for instance twisted pairs, between a central office and a subscriber, which is characterized in that it makes use of the time domain reflectometry.

The invention provides an apparatus for testing the properties, such as the attenuation, of telephone lines comprising copper pairs, for instance twisted pairs,

between a central office and a subscriber, which is characterized in that it comprises time domain reflectometry means.

Other features and advantages of the invention will appear with the following description of certain of its embodiments, this description being made in connection with the following drawings, wherein:

figure 1 represents the application of a method according to the invention to the estimation of defects of a telephone line for ADSL services,

figure 2 is a schematic diagram showing an equipment according to the invention, this diagram representing also the operation of the equipment, i.e. the method according to the invention,

figure 3 shows an example of pulses generated by the equipment represented on figure 2, and

figures 4 to 8 are diagrams showing signals at different locations on the receiving side of the equipment represented on figure 2.

The time domain reflectometry method according to the invention was developed in order to test copper lines 10 between a central office 12 of a telephone operator and subscribers 14. The goal of the test is to check whether the copper pair 10 is able to comply with ADSL services, i.e. whether its attenuation is inferior to a maximum attenuation imposed by standards. Moreover, this method provides the possibility to localize defects of the line 10.

In the schematic example shown on figure 1, a part 16 of the line 10 which is relatively close to the central office or station 12 is subject to humidity; after this defect 16, in the direction from the office 12 to the subscriber 14, the line presents a defect 18 corresponding to a bridge tap, i.e. a derivation.

In the preferred embodiment of the method according to the invention, a set of pulses are simultaneously or sequentially generated (sequentially in the example) at the central station 12, each pulse covering a given bandwidth and the bandwidths of all the pulses are overlapping. The whole bandwidth formed by these pulses is wide, for instance, from 20 kHz to 6 MHz.

The set of pulses generated sequentially are transmitted from the office 12 on the line 10 and they are reflected by the defects 16, 18, as well as by the line end 21, i.e. by subscriber 14. In fact, it is known that a telephone set which is not in operation is a pure reflector.

The reflections or echoes are detected and processed at the central office 12 according to the equipment and method represented on figures 2-8 and these processed echoes provide information about the line 10 and its defects.

In the simplified example represented on figure 2, the vertical line 22 on the left represents the frequency and the diagram is, in the horizontal direction, separated in five zones 24, 26, 28, 30, and 32 from the left to the right. The zone 24 corresponds to the transmission of pulses at the central office 12. The zone 26 represents the path of the pulses from the central office 12 to the subscriber 14 and back from the subscriber 14 to the central office 12. The zone 28 represents the processing of the received echoes, each processing corresponding to a given bandwidth. The zone 30 represents the sum ot the echoes which are processed in zone 28 and the zone 32 represents the spectrum of the transmitted, filtered and reconstructed pulses.

In the simplified example, three pulses 40, 42, 44 are provided. The pulse 40 has a spectrum which covers the low frequencies, the pulse 42 has a spectrum which covers the medium frequencies and the pulse 44 has a spectrum which covers the high frequencies. For instance, the pulse 40 covers 12.5 kHz to 960 kHz, the pulse 42 covers 512 KHz to 2.6 MHz and the pulse 44 covers 1.65 MHz to 6.3 MHz. The frequency bands of these pulses are overlapping. More precisely, the higher part of the frequency band of pulse 40 overlaps with the lower part of the frequency band of pulse 42 and the higher part of the frequency band of the pulse 42 overlaps with the lower part of the frequency band of pulse 44.

Moreover, the overlapping portions of the spectra of the pulses are such that, after reflection, reception and processing, the amplitude of the added overlapped parts equals the amplitude of the non-overlapping parts. In other words, after reception, the spectrum of all the pulses is practically flat, as shown on zone 32 of figure 2.

For instance, the higher part 40_1 of the frequency band of pulse 40 varies as a sine function and the overlapping part of the lowest portion 42_1 of the frequency band of pulse 42, varies as a cosine function. As in zone, or step, 30, as explained herein after, the squares of the amplitudes of the spectra are added, the overlapping regions 40_1, 42_1 provide after the final processing: $\sin^2 + \cos^2 = 1$.

The method provides also, on the transmission side, a gain (amplification or attenuation) for each pulse. For the sake of simplicity of the drawing, only the amplification and attenuation for pulse 42 have been represented. To the pulse 42 corresponds a gain represented by an amplifier 48, and on the receiving side (zone 28), the inverse gain 50 is provided in order that the resulting spectra (zone 32) be flat as explained herein above.

Each gain may be different from one bandwidth to another bandwidth, in order to comply with the requirements of the standard which may impose different constraints on the admissible maximum power for different bandwidths.

On the receiving side, for each bandwidth, a processing is performed to drastically reduce the noise: a synchronous averaging 52, followed by a matched filtering 54 and a denoising 56. Each signal at the corresponding bandwidth, after having been processed by the synchronous averaging 52, the matched filtering 54 and the denoising 56, is submitted to a reconstruction step (zone 30) 60 which sums the outputs of the processing steps. Because of the matched filter properties, the summation of the outputs of the processing steps is equivalent in the frequency domain, to the following equation:

$\sum_i |P_i(f)|^2 = 1$, where $P_i(f)$ is the transfer function for each pulse.

Figure 3a shows the variation with time (in abscissa) of the pulse 40. The curve 62 corresponds to the real part of the pulse, the curve 64 represents the variation of the imaginary part, and the curve 66 represents the envelope of the pulse.

The diagram of figure 3b shows the spectrum of the pulses 62 and 64, i.e. the Fourier transform of said pulses. As shown, the spectrum, which extends from 20 kHz to 200 kHz presents a flat part 68, a raising edge 70 and a falling edge 72. As mentioned before, the falling edge has, for instance, the shape of a sine function.

The diagrams of figure 4 represent the signals obtained after synchronous averaging 52 and before matched filtering 54.

Figure 4a represents the variation with time of the real part of the signal for the pulses 44 at high frequencies, and figure 4b represents the variation with time of the imaginary part for the signal at the output of a synchronous averaging corre-sponding to the same high frequency pulses 44.

The diagrams of figure 4c and figure 4d correspond, respectively, to the real and imaginary parts of the complex signal obtained after synchronous averaging for the medium frequency pulses and figure 4e and figure 4f are diagrams corresponding also to the real and imaginary parts of the signal obtained at the output of the synchronous averaging 52 for the low frequency pulses.

Figure 4a and figure 4b show that, for high frequencies, the echoes present a pulse 80. This pulse corresponds to a defect 16 close to the central office 12, because the attenuation on the line increases sharply with the frequency and the distance.

For medium frequencies (figure 4c and figure 4d), the diagram shows two echoes 82 and 84 corresponding to defects 16 and 18 and, for low frequencies (figure 4e and figure 4f), the diagram shows several echoes corresponding to defects 16, 18, and to the line end 21. It is recalled that, in this example, the load coil defect 20 is not present.

The diagrams of figure 5 are similar to the diagrams of figure 4, but they represent the echoes obtained after the matched filtering 54. The matched filtering comprises a step of correlating the received pulse with the transmitted pulse. This matched filtering provides a further sharp decrease of the noise, as shown by comparison of the diagrams of figure 4a to figure 4f with the corresponding diagrams of figures 5a to 5f.

A further reduction of noise, more particularly for the high frequency pulses is obtained with the denoising 56. This further noise suppression comprises a step of determining a threshold below which the values of signal and noise are set to zero, only the echoes which are above this threshold being taken into account.

The threshold is, in an example, determined by an estimation of the noise at the end (on the right of diagrams of figure 5) of the signals obtained after matched filtering. In fact, the ending time corresponds to the end of the line, at the subscriber's location, for which no signal can be detected in medium and high frequencies; therefore, the signal end corresponds, in practice, exclusively to noise for high and medium frequencies. The noise is estimated by the variance of the signal at said signal end and the threshold is determined by multiplying the square root of this variance by a predetermined factor, for instance 2. More precisely, the noise variance is estimated after the line end echo, i.e. on a noise alone segment.

It is to be noted that the denoising is limited to the signals which appear after the last echo. No denoising is performed on signals appearing before the last echo.

The result of the denoising appears on the diagrams of figure 6a to figure 6f which are similar to the diagrams of figure 4a to figure 4f.

Figure 7 is a diagram showing the variation with time of the signal after the summing of the outputs of the processing step for the three frequency bands (output of adder 60).

This diagram shows that the time domain reflectometry method of the invention provides, in this example, three echoes 96, 98 and 100. The first echo corresponds mainly to defect 16, the second echo to defect 18 and the third to the line end 21.

On the diagram of figure 8, the abscissa is the time t and the ordinate is the frequency f. It can be seen that, to the three lines 96, 98, 100, correspond lines 102, 104 and 106. The line 102 extends on the whole frequency band, the line 104 corresponds to the medium frequencies and the last line 106 is limited to low frequencies.

Therefore, the diagrams obtained with figure 7 and figure 8 show that the method according to the invention provides, with only one measurement, information about the properties of the line and the defects, more particularly about the location of such defects.

More generally, the method according to the invention provides directly an estimation of the reflectometric impulse response of a line, with a good time accuracy and a high signal-to-noise ratio at any distance.

CLAIMS

1. A time domain reflectometry method for determining properties of a transmission channel, characterized in that it comprises the steps of generating, at one end of the channel, a plurality of pulses (40, 42, 44) covering different frequency bands, and of processing the echoes provided by these pulses at the same end (12) of the channel.
2. A method according to claim 1, characterized in that the frequency bands of the generated pulses are overlapping.
3. A method according to claim 2, characterized in that the overlapping of the frequency bands is such that, after reflection and processing, the frequency spectrum is practically flat.
4. A method according to any of claims 1-3, characterized in that each generated pulse is provided with a given amplification (48) or attenuation and the received pulses are provided with the corresponding attenuation (50) or amplification.
5. A method according to any of the previous claims, characterized in that the signals received are submitted to a synchronous averaging (52).
6. A method according to any of the previous claims, characterized in that the received signals are submitted to a matched filtering (54).
7. A method according to any of the previous claims, characterized in that the received signals are submitted, at least for the medium and high frequency pulses, to a noise suppressing step (56) comprising the estimation of the noise for the part of the received signal after the channel end echo and the determination of a threshold above which the signals are taken into consideration.
8. A method according to any of the previous claims, characterized in that the received signals are processed in their own frequency bands and added (60) after processing.
9. A method according to claim 8, characterized in that the variation with time of the modulus of the received signals is detected and/or the variation with time of the frequency of the received signals is detected.
10. A method according to any of the previous claims, characterized in that the pulses are complex analytical pulses.
11. A method according to any of the previous claims, characterized in that the frequency bandwidth and the amplitude of the low frequency pulses (40) are selected according to the channel attenuation and its compliancy in terms of egress.

12. A method according to any of the previous claims characterized in that the pulses are generated sequentially or simultaneously.

13. Application of the method according to any of the previous claims to the determination of locations of defects of the channel.

14. Application of the method according to any of claims 1-12 to the properties of a telephone line between a central office (12) and a subscriber (14), the measurement being made at the central office.

15. A method for testing the properties, such as the attenuation, of telephone lines comprising copper pairs, for instance twisted pairs, between a central office and a subscriber, characterized in that it makes use of the time domain reflectometry.

16. A method according to claim 15, characterized in that the time domain reflectometry comprises the steps of generating, at one end of the channel, a plurality of pulses (40, 42, 44) covering different frequency bands, and of detecting the echoes provided by these pulses at the same end (12) of the line.

17. An apparatus for testing the properties, such as the attenuation, of telephone lines comprising copper pairs, for instance twisted pairs, between a central office and a subscriber, characterized in that it comprises time domain reflectometry means.

18. An apparatus according to claim 17, characterized in that it comprises means for generating, at one end of the line, a plurality of pulses (40, 42, 44) covering different frequency bands, and means for processing the echoes provided by these pulses at the same end (12) of the channel.

19. An apparatus according to claim 18, characterized in that the means for generating a plurality of pulses covering different frequency bands are such that the frequency bands are overlapping.

20. An apparatus according to claim 19, characterized in that it comprises means for processing the reflected pulses such that the frequency spectrum is practically flat after reflection and processing.

21. An apparatus according to any of claims 18-20, characterized in that the pulse generating means comprise, for each generated pulse, amplification (48) or attenuation means and in that on the received in side, it comprises, for each pulse, complementary attenuation (50) or amplification means.

22. An apparatus according to any of claims 18-21, characterized in that it comprises synchronous averaging means for the received signals.

23. An apparatus according to any of claims 18-22, characterized in that it comprises matched filtering means (54) for the received signals.

24. An apparatus according to any of claims 18-23, characterized in that it comprises noise suppressing means (56) for the received signals, these noise suppressing means including means for estimating the noise for the part of the received signals after the channel end echo and means for determining a threshold above which the signals are taken into consideration.

25. An apparatus according to any of claims 18-24, characterized in that it comprises means for processing the received signals for each frequency band and means for adding the processed signals.

26. An apparatus according to claim 25, characterized in that it comprises means for detecting the modulus of the received signals and/or the variation with time of the frequency of the received signals.

27. An apparatus according to any of claims 18-26, characterized in that it comprises means for receiving complex analytical pulses.

28. An apparatus according to any of claims 18-27, characterized in that it comprises means for selecting the frequency bandwidth and the amplitude of the low frequency pulses according to the line attenuation and its compliancy in terms of egress.

29. An apparatus according to any of claims 18-28 characterized in that it comprises means for generating the pulses sequentially or simultaneously.

ABSTRACT

METHOD AND APPARATUS FOR DETERMINING PROPERTIES OF A TRANSMISSION CHANNEL

The invention concerns a time domain reflectometry method for estimating properties of a transmission channel, for instance a channel for transmitting electric or acoustic signals.

This method comprises the steps of generating, at one end of the channel, a plurality of pulses (40, 42, 44) covering different frequency bands, and of processing the echoes provided by these pulses at the same end of the channel.

The frequency bands of the generated pulses are preferably overlapping.

Application to the testing of ADSL services.

Figure 2:

FIG_1

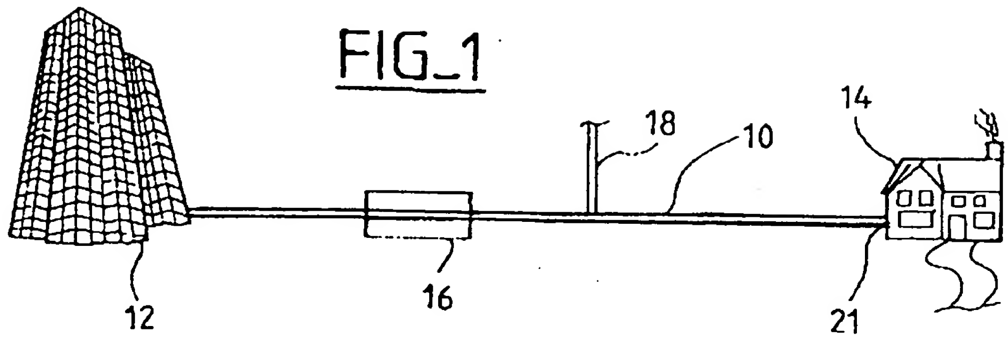
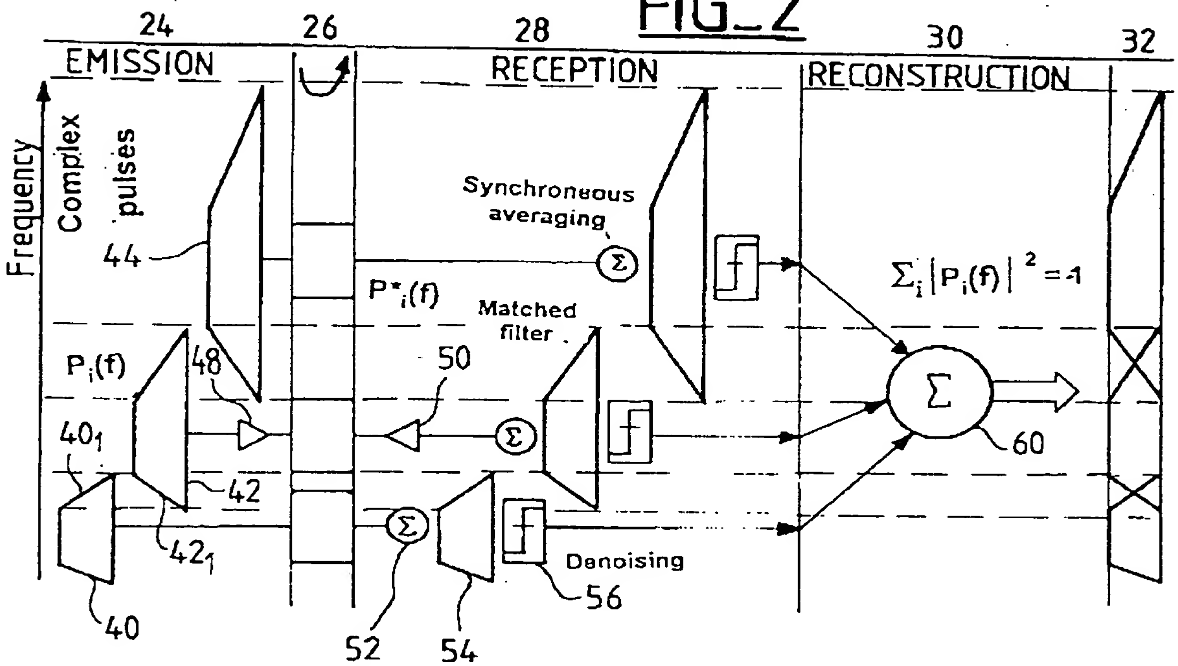


FIG_2



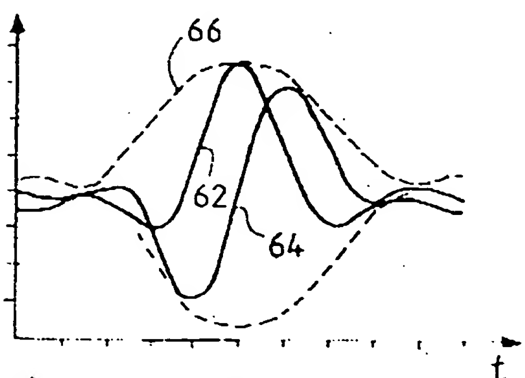


FIG_3a

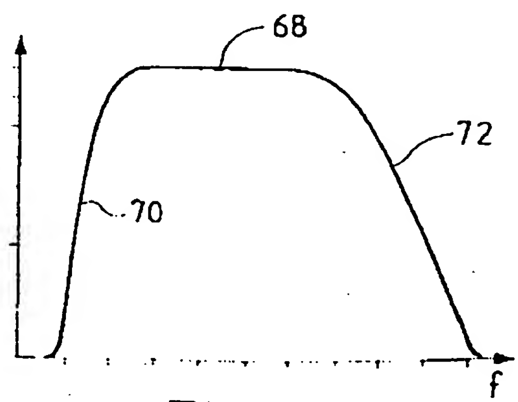


FIG_3b

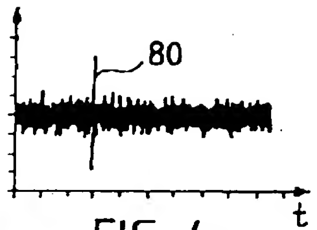


FIG_4a

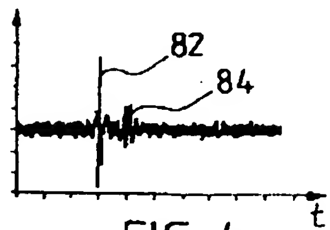


FIG_4c

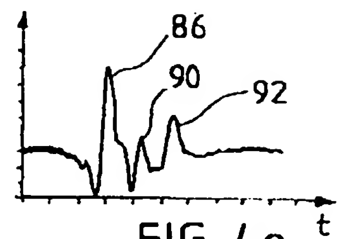


FIG_4e

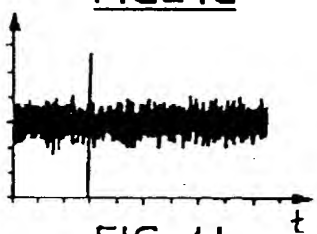


FIG_4b

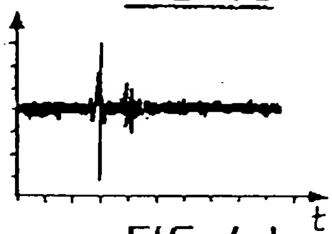


FIG_4d

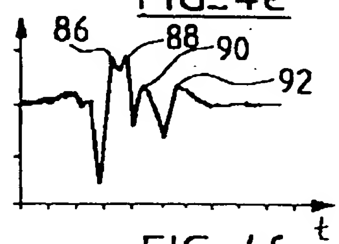


FIG_4f

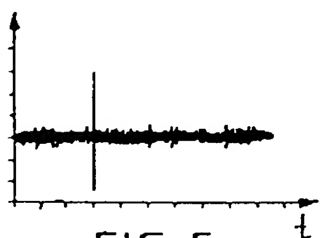


FIG_5a

FIG_5c

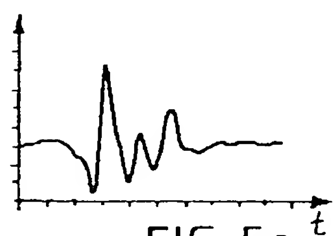


FIG_5e

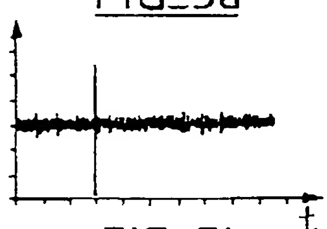


FIG_5b

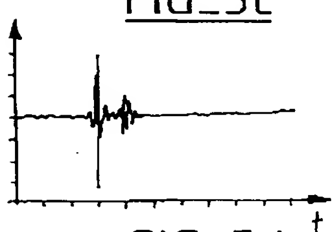


FIG_5d

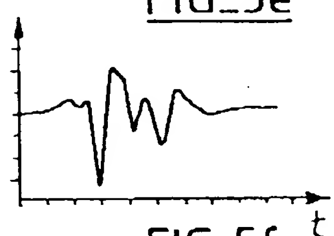


FIG_5f

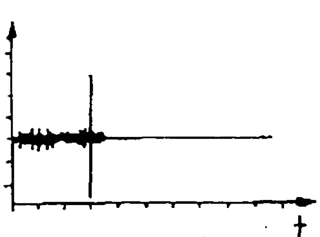


FIG_6a

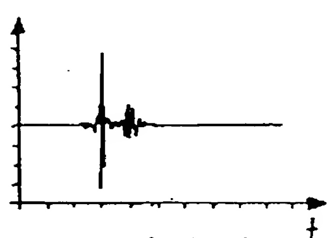


FIG_6c

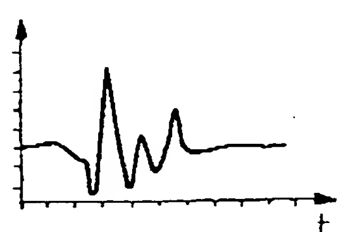


FIG_6e

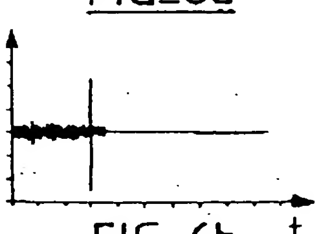


FIG_6b

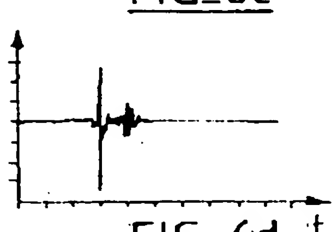


FIG_6d

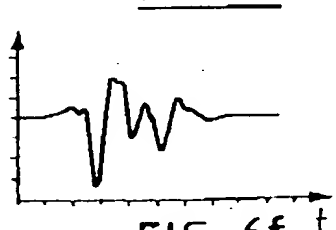


FIG_6f

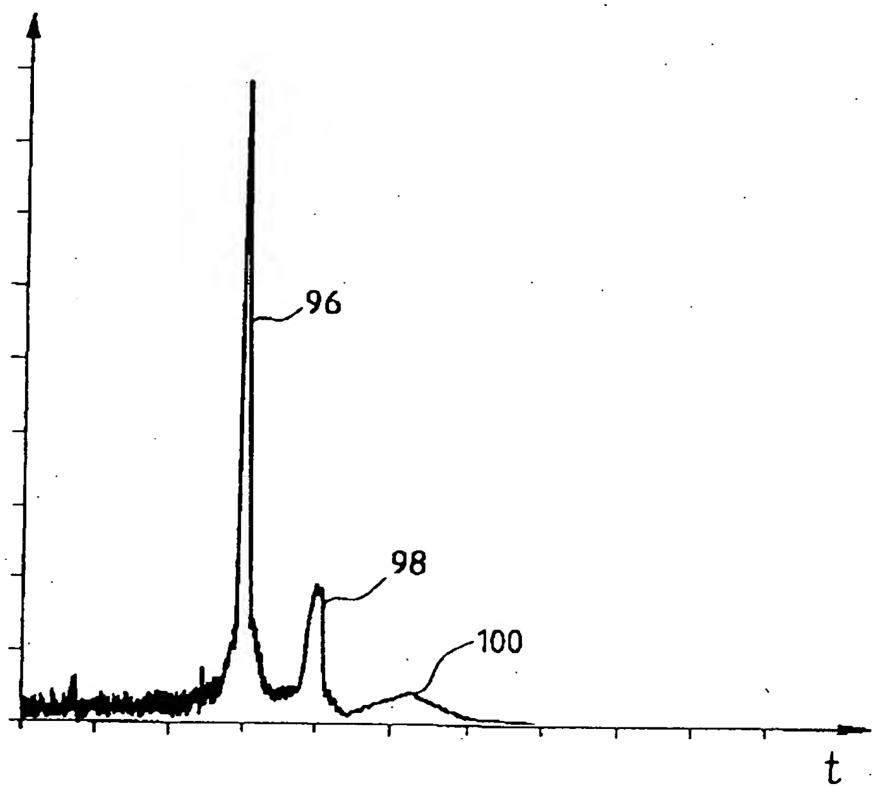


FIG_7

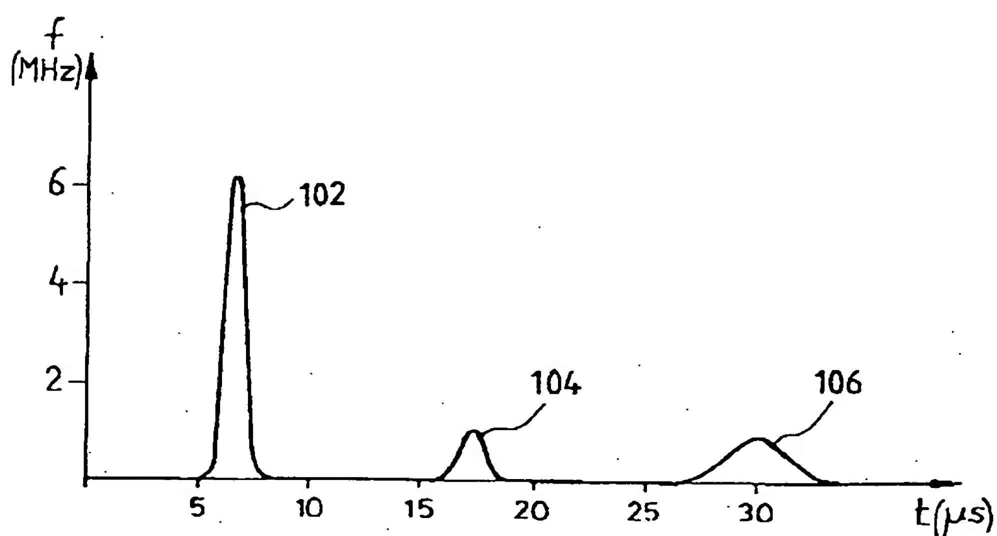


FIG_8